TOTAL MAXIMUM DAILY LOAD (TMDL) DEVELOPMENT

For FECAL COLIFORM in the

CROOKED CREEK WATERSHED

(HUC 03160110)

Cullman County, Alabama

EPA
United States
Environmental Protection
Agency

Region 4
serving the
southeast

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LIST OF ABBREVIATIONS

BMP   Best Management Practices

CAFO   Concentrated Animal Feeding Operation

CFS   Cubic Feet per Second

DEM   Digital Elevation Model

DMR   Discharge Monitoring Report

EPA   Environmental Protection Agency

GIS   Geographic Information System

HSPF   Hydrological Simulation Program - FORTRAN

HUC   Hydrologic Unit Code

LA   Load Allocation

MGD   Million Gallons per Day

MOS   Margin of Safety

MPN   Most Probable Number

MRLC   Multi-Resolution Land Characteristic

NPDES   National Pollutant Discharge Elimination System

NPSM   Nonpoint Source Model

NRCS   Natural Resources Conservation Service

RF3   Reach File 3

RM   River Mile

STORET   STORage RETrieval database

TMDL   Total Maximum Daily Load

USGS   United States Geological Survey

WCS   Watershed Characterization System

WLA   Wasteload Allocation

1.0 EXECUTIVE SUMMARY: CROOKED CREEK

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) requires states to identify waterbodies which are not meeting their designated use and to determine the Total Maximum Daily Load (TMDL) for pollutants causing the use impairment. TMDLs are the sum of individual wasteload allocations for point sources (WLAs), load allocations (LAs) for nonpoint sources including natural background levels, and a margin of safety (MOS).

The State of Alabama has identified Crooked Creek as partially supporting its designated use of Fish and Wildlife for ammonia, organic enrichment/dissolved oxygen (OE/DO), and pathogens. This TMDL addresses only the impairment from pathogens. Crooked Creek in Cullman County lies within the Sipsey Fork of the Black Warrior River basin, hydrologic unit 03160110. Crooked Creek is a tributary to Smith Lake; its watershed is forested and agricultural with little urban or developed area and is approximately 36,366 acres (56.8 sq. mi.).

Fecal coliform is used as the indicator for pathogen TMDLs in Alabama. A geometric mean of 200 colonies/100 mL was established as the target for this TMDL. Water quality data collected on Crooked Creek in 1991 and 1997 was used for Alabama's 1998 303(d) listing of the stream from its headwaters to Smith Lake since it partially supported its designated use because of ammonia, OE/DO, and pathogen concentrations.

The Nonpoint Source Model (NPSM) was chosen as the model to complete this TMDL. The Watershed Characterization System (WCS), a geographic information system (GIS) interface, was used to display, analyze and compile spatial and attribute data. Crooked Creek was delineated into a single subwatershed based on a Reach File 1 (RF1) stream coverage and a Digital Elevation Model (DEM) of the area. The farthest downstream point of the delineation was the water quality sampling station CRK-5. A continuous simulation period of 10 years (1/1/89 – 12/31/98) was the basis of the TMDL.

Loads from existing sources contributing to nonpoint sources were combined to form three load groups. The first group, runoff from all lands, contributed 4.28×10^{15} counts/30 days and consisted of deposits from grazing animals, an estimate of loading based on the deer population (wildlife) and loads from land applied manure. The second group, leaking septic systems, contained only information related to septic systems and contributed 1.20×10^{11} counts/30 days. The final group, miscellaneous sources, consisted of livestock with stream access and an estimate of unknown instream sources and illicit discharges contributed 4.89×10^{11} counts/30 days to the total existing load. There was one point source, West Point High School (NPDES Permit AL0051136), that contributes an estimated 1.02×10^{10} counts/30 days.

An allocation scenario that predicts compliance with instream water quality standards requires individual reductions from runoff from all lands (87%), leaking septic systems (60%) and miscellaneous sources (24%). The components of the resulting TMDL are summarized below.

Watershed	WLA	LA	MOS	TMDL
	cnts/30 days	cnts/30 days		cnts/30 days
Crooked Creek	1.02×10^{10}	5.73×10^{14}	Explicit+Implicit	5.73×10^{14}

Using a 10-year simulation period offered the opportunity to observe seasonal dependency. Loading rates were varied monthly in the NPSM. The varying rates were based on reports obtained from the WCS and monthly application rates of animal manure to cropland and pastureland.

Both an explicit and implicit margin of safety was incorporated into the TMDL. The explicit MOS was applied only to the load allocation by reducing the simulated geometric mean concentration to 180 counts/100 mL rather than the water quality criterion of 200 counts/100 mL (a reduction of 20 counts/100 mL). The implicit MOS is based on conservative modeling techniques, including the use of the most stringent water quality standard year-round, loads from leaking septic systems are assumed to be directly connected to the stream, and nonpoint loads area are assumed to have direct paths to streams.

Fecal coliform loads for Crooked Creek are attributed to sources modeled as both point and nonpoint sources. This combination of sources makes it difficult to predict when the critical peak will occur; therefore, a long-term analysis was employed. Use of a long-term analysis allowed the prediction of fecal loads for many rainfall scenarios and therefore, a representative critical peak. For Crooked Creek, the highest violations of the 30-day geometric mean occurred on 6/22/97. The resulting critical period was 5/24/97 to 6/22/97.

2.0 TMDL: CROOKED CREEK

2.1 Introduction

2.1.1 The TMDL Process

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) requires states to identify waterbodies which are not meeting their designated use and to determine the Total Maximum Daily Load (TMDL) for pollutants causing the use impairment. The TMDL process establishes the allowable loadings of pollutants for a waterbody based on the relationship between the pollution sources and instream water quality conditions, so that states can establish water quality based controls to reduce pollution and restore and maintain the quality of their water resources (USEPA 1991).

TMDLs are the sum of individual wasteload allocations for point sources (WLAs), load allocations (LAs) for nonpoint sources including natural background levels, and a margin of safety (MOS). The margin of safety can be included either explicitly or implicitly and accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. If the MOS is accounted for explicitly, a portion of the total TMDL is specified; in most cases, the MOS is implicit and accounted for with conservative modeling techniques. A TMDL is denoted by the equation:

$$TMDL = \Sigma WLAs + \Sigma LAs + MOS$$

TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure. For bacteria, TMDLs are expressed in terms of organism counts (or resulting concentration), in accordance with 40 CFR Part 130.2(1).

2.1.2 Watershed Description

The State of Alabama has identified Crooked Creek as partially supporting its designated use for Fish and Wildlife for ammonia, OE/DO, and pathogens. It has been described (ADEM 1999) as having habitat quality that was "slightly impaired"; macroinvertebrates that were "slightly impaired"; and a fish community that was in "fair condition." Crooked Creek in Cullman, County lies within the Sipsey Fork of the Black Warrior River basin, hydrologic unit 03160110 (see Figure 1). Crooked Creek is a tributary to Smith Lake; its watershed is forest and agricultural with little urban or developed area and is approximately 36,366 acres (56.8 sq. mi.). Table 1 provides a breakdown of land use in acres, square miles and percent of total.

Table 1. Crooked Creek Watershed Landuse Distribution

Landuse	Acres	Square Miles	Percent of Total Watershed
Cropland	3,565	5.6	9.8%
Pastureland	8,755	13.7	24.1%
Forest Land	23,839	37.2	65.6%
Urban Land	207	0.3	0.6%
Total	**36,366**	**56.8**	**100.0%**

Crooked Creek Location Map

Cullman County, Alabama

LEGEND
Point Source
Populated Places
Alabama Roads
County Boundaries
Water Quality Station
Streams
Crooked_layout.shp
Catalog Unit Boundaries

Morgan County   Cullman County

State Hwy. 157

Winston County

AL0051136

Cullman

Good Hope

CRK-5
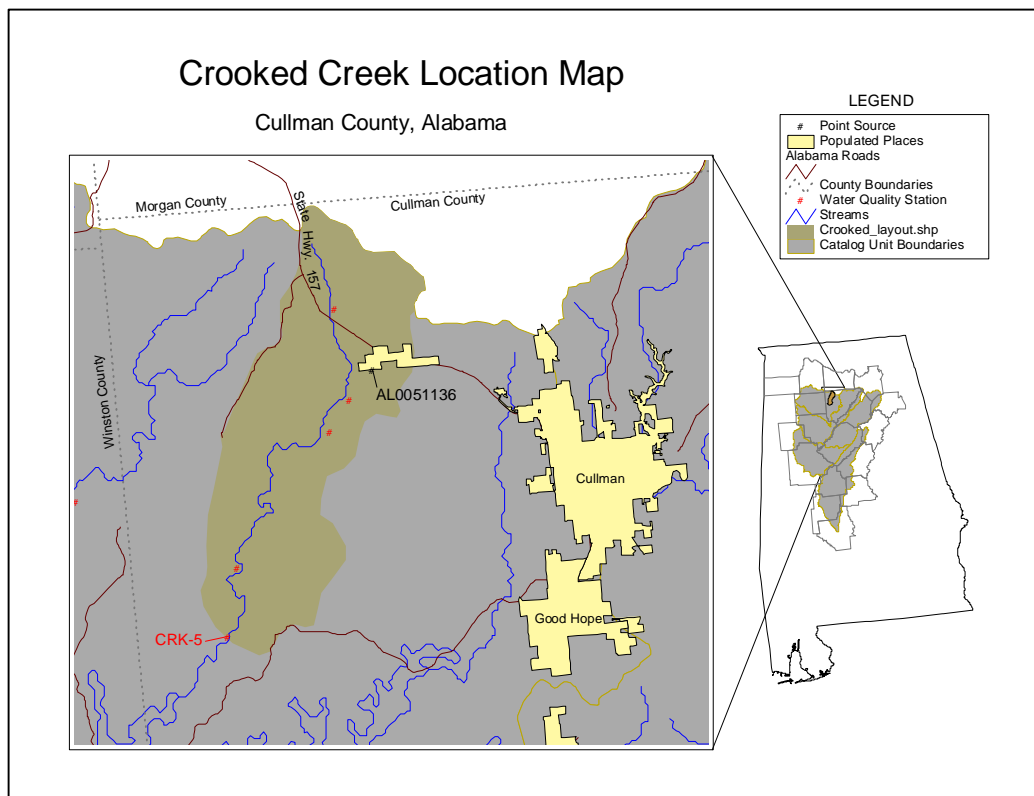
Figure 1. Crooked Creek watershed location map.

Crooked Creek Landuse
Cullman County, Alabama

Crooked Creek

Cullman County
FIPS 1043

Winston County
FIPS 1133

Catologing Unit 03160110

Statistical Data

Total Drainage Area	56.8	SqMi.
Total Drainage Area	36,366	Acres
Urban Impervious	78.5	Acres
Urban Pervious	128.6	Acres
Crop Land	3565	Acres
Pasture Land	8755	Acres
Forest	23,839	Acres

LEGEND
Sample Locations
303d Listed Waters
County Boundaries
Cataloging Unit Boundaries
Streams (RF1)
Crooked Creek W/S Boundary
Landuse
Urban
Barren or Mining
Transitional
Agriculture - Cropland
Agriculture - Pasture
Forest
Upland Shrub Land
Grass Land
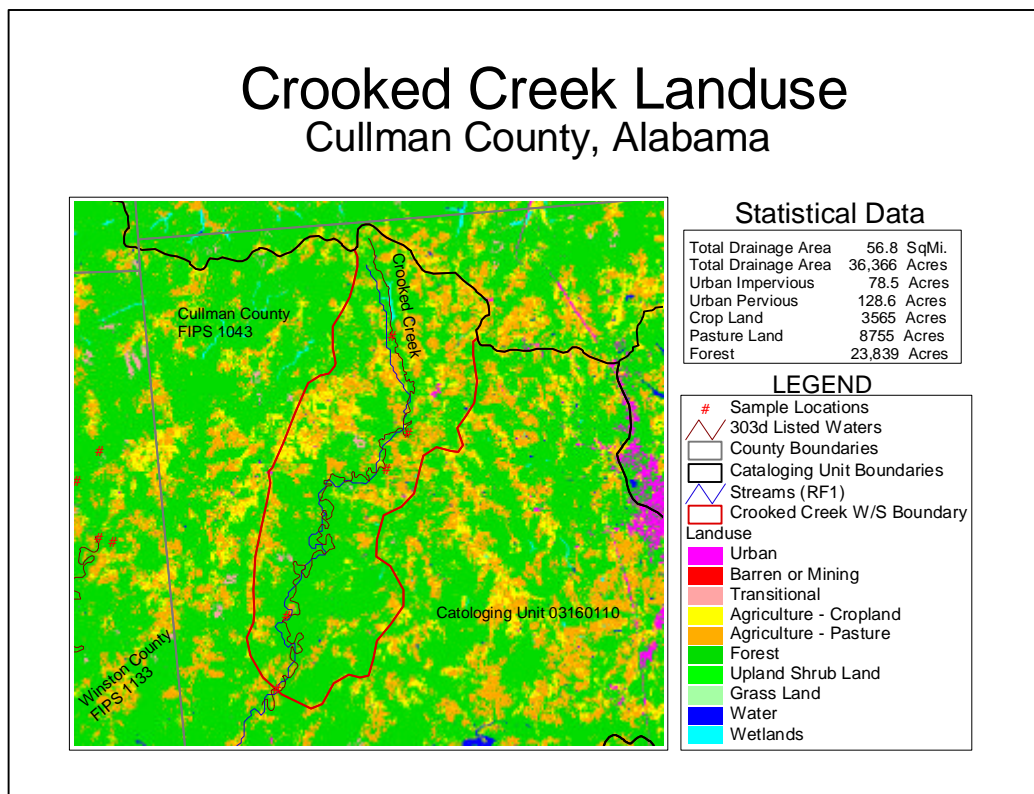Water
Wetlands

Figure 2. Crooked Creek land use distribution and statistics.

2.1.3 Designated Use of the 303(d) Stream

Crooked Creek has a use classification of Fish and Wildlife. Usage of waters in this classification is described in ADEM Admin. Code R. 335-6-10-.09(5)(a), (b) (c) and (d).

(a). Best usage of waters:

> Fishing, propagation of fish, aquatic life, and wildlife, and any other usage except for swimming and water-contact sports or as a source of water supply for drinking or food processing purposes.

(b). Conditions related to best usage:

> The waters will be suitable for fish, aquatic life and wildlife propagation. The quality of salt and estuarine waters to which this classification is assigned will also be suitable for the propagation of shrimp and crabs.

(c). Other usage of waters:

> It is recognized that the waters may be used for incidental water contact and recreation during June through September, except that water contact is strongly discouraged in the vicinity of discharges or other conditions beyond the control of the Department or the Alabama Department of Public Health.

(d). Conditions related to other usage:

> The waters, under proper sanitary supervision by the controlling health authorities, will meet accepted standards of water quality for outdoor swimming places and will be considered satisfactory for swimming and other whole body water-contact sports.

2.2 TMDL Indicators and Numeric Targets

Fecal coliform is used as the indicator for the pathogen TMDL. The standard for acceptable bacteria levels for the Fish and Wildlife use classification are presented in ADEM Admin. Code R. 335-6-10-.09(5)(e)7.(i) and (ii).

i.   Bacteria of the fecal coliform group shall not exceed a geometric mean of 1,000 colonies/100 mL; nor exceed a maximum of 2,000 colonies/100 mL in any sample. The geometric mean shall be calculated from no less than five samples collected at a given station over a 30-day period at intervals not less than 24 hours.

ii.   For incidental water contact and recreation during June through September, the bacterial quality of water is acceptable when a sanitary survey by the controlling health authorities reveals no source of dangerous pollution and when the geometric mean fecal coliform organism density does not exceed 100 colonies/100 mL in coastal waters and 200 colonies/100 mL in other waters. The geometric mean shall be calculated from no less than five samples collected at a given station over a 30-day period at intervals not less than 24 hours. When the geometric mean fecal coliform organism density exceeds these levels, the bacterial water quality shall be considered acceptable only if a second detailed sanitary survey and evaluation discloses no significant public health risk in the use of the waters. Waters in the immediate vicinity of discharges of sewage or other wastes likely to contain bacteria harmful to humans, regardless of the degree

of treatment afforded these wastes, are not acceptable of swimming or other whole body water-contact sports.

Incidental water contact and recreation is the most stringent of the use classifications. The geometric mean criterion of 200 counts/100 mL was used as the target level for TMDL development.

2.3 Water Quality Assessment

Water quality data collected on Crooked Creek in 1991 and 1997 was used for listing the stream on Alabama's 1998 303(d) list and is shown in Table 2. Insufficient data were collected to calculate 30-day geometric mean values, however, one sample collected in July 1997 exceeded the maximum daily value of 2000 counts/100 mL. As a result, Crooked Creek, from its headwaters to Smith Lake, was listed as partially supporting its designated use and was scheduled for TMDL evaluation. The water quality sampling station for Crooked Creek, CRK-5 is located on Crooked Creek at Cullman County Road 7, north of Crane Hill. The station location is shown on Figure 1.

Table 2 . Water quality sampling data collected at CRK-5 for Crooked Creek.

Date	Fecal Coliform Concentration (counts/100 mL)	Date	Fecal Coliform Concentration (counts/100 mL)
6/4/1991	260	6/1/1997	250
7/9/1991	130	7/1/1997	>6000
8/9/1991	340	8/5/1997	650
9/10/1991	140	9/2/1997	62
10/7/1991	50		

2.4 Source Assessment

2.4.1 Background

Wildlife, including deer, raccoons, wild turkeys, waterfowl, etc., is considered significant contributors to background concentrations of fecal coliform. Due to the lack of population estimates for raccoons, waterfowl and other wildlife that may inhabit the watershed, the deer population was used to estimate the fecal coliform load from wildlife. Based on discussions with ADEM, the population of deer in the watershed was estimated at 45 deer/sq. mile. The fecal coliform loading rate from deer was estimated by linear interpolation using the rates for other animals, such as turkey and cattle, reported in Metcalf and Eddy (1991). The interpolation was based on animal weight and fecal coliform production rate. The resulting loading rate from deer was estimated at 5.0×10^8 counts/animal/day.

2.4.2 Point Source Assessment

A point source can be defined as any discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Point source discharges of industrial wastewater, treated sanitary wastewater, storm water associated with industrial activity, or storm water from municipal storm sewer systems that serve

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over 100,000 people must be authorized by National Pollutant Discharge Elimination System (NPDES) permits.   Permitted facilities impacting the impaired stream are entered as point sources having constant flow and concentration based on design flow and permit limits for fecal coliform bacteria. NPDES permitted facilities are the only contributions to the wasteload allocation (WLA) component of the TMDL. There is one NPDES permitted facility, West Point High School (NPDES Permit AL0051136), located within the Crooked Creek watershed. The fecal coliform loading from this facility was estimated based on the design flow of the facility of 0.045 MGD and the permit limits for fecal coliform bacteria of 200 counts/100 mL (based on a geometric mean concentration). The resulting contribution of fecal coliform from this facility was calculated to be 1.02 x 10^{10} counts/30 days. All future NPDES facilities will be required to meet end-of-pipe criteria equivalent to the water quality criterion for fecal coliform bacteria of 200 counts/100 mL.

2.4.3 Nonpoint Source Assessment

Nonpoint sources of fecal coliform bacteria are diffuse sources that cannot be identified as entering the waterbody at a single location. These sources generally involve land activities that contribute fecal coliform bacteria to streams during rainfall runoff events. Fecal coliform loading rates for various livestock were estimated to be; 1.06×10^{11} counts/day/beef cow, 1.04×10^{11} counts/day/dairy cow, 1.24×10^{10} counts/day/hog, 1.38×10^{8} counts/day/chicken and 4.18×10^{8} counts/day/horse (NCSU 1994). All sources considered to be nonpoint sources contribute to the load allocation (LA) portion of the TMDL. Typical nonpoint sources of fecal coliform bacteria include:
- Septic systems
- Livestock in streams
- Land application of manure
- Wildlife
- Urban runoff
- Pastures

Septic Systems and Urban Runoff

Leaking septic systems were modeled as point sources with a constant flow and concentration. The number of people in the Crooked Creek watershed that may be on septic systems was estimated using 1997 U. S. Census Bureau county data and are shown in Table 3. Using best professional judgment, it was assumed that 10 percent of the total septic systems in the watershed would leak or fail. Literature values were used to estimate the loadings from failing septic systems in the watershed using a representative effluent flow and concentration. Horsley and Witten (1996) estimate septic effluent concentrations as 10^{6} counts/100 mL with an average daily discharge of 70 gallons/person-day.   Using this information, the load from failing septic systems was estimated to be 1.2 x 10^{11} counts/30 days. This value is a conservative estimate of the load as it does not account for die-off or attenuation of loadings of fecal coliform from failing septic systems to the stream. Additionally, stormwater runoff from rural areas can contribute to fecal coliform nonpoint source loads by delivering litter and the waste of domestic pets and wildlife to the stream.

Table 3. Estimated Septic Populations.

Watershed	Estimate of Individuals on Septic Systems
Crooked Creek	3,784

Livestock in Streams and Unknown Sources

Livestock often have access to small streams in their grazing areas. Loads attributed to livestock in streams were included as an hourly point source of constant flow and concentration. Initial loads were based on the beef cattle population in the watershed and literature values for fecal coliform bacteria produced daily per beef cow. In computing the load, it was assumed 50 percent of the beef cattle had access to the streams and of those, 25 percent deposit wastes in or near the stream bank. Estimates of beef cattle in the watershed as determined from county agricultural census data (USDA 1997) are shown in Table 4. During the water quality calibration, this load can be adjusted to better match observed low flow concentrations. The element, livestock in streams, is defined as a nonpoint source but was modeled as a point source because of model limitations. Livestock contributions were then included correctly in the load allocation (LA) portion of the TMDL.

Land Application of Animal Manure

Beef cattle and poultry are the predominant livestock in the watershed. Estimates of the numbers of livestock in the watershed are from U.S. Department of Agriculture (USDA) National Agriculture Statistics System (USDA 1997) and are shown in Table 4. ADEM requires a general NPDES permit for all concentrated animal feeding operations (CAFOs) in excess of 1000 animal units and for poultry operations in excess of 125,000 birds.   The general NPDES permit for CAFOs is a 'no discharge' permit except during the 25-year, 24-hour storm event, and then the CAFO facility can discharge only process overflow wastewater to the stream. Based on the number of cattle and poultry animals in the watershed, CAFOs could be causing or contributing to the impairment of Crooked Creek as indicated by the 303(d) listing.

Agricultural operations with confined animals generally stack or hold their manure until it can be applied to cropland or pasture land.   Poultry litter that is not stockpiled can be used as a feed material for cows, composted or sold. Estimated application rates used in the model vary monthly and by type of animal operation and are listed in Table 5. In the Crooked Creek watershed, poultry litter is predominately spread on pastureland. If the litter is not spread at agronomic rates, then a large portion of the fecal coliform bacteria present in the litter could wash off to the stream during a storm event.

Table 4. Estimated number of agricultural animals in the Crooked Creek watershed based upon agricultural census data (USDA 1997).

Watershed	Estimated Number of Animals
Beef Cattle	4,478
Poultry	2,733,462
Swine	42
Dairy Cattle	217

Table 5. Estimated land application rates for confined animal manure in Crooked Creek (NRCS 2000).

Operation	% Of One Years Confined Manure Applied In Each Month												% Applied to	
	January	February	March	April	May	June	July	August	September	October	November	December	Pasture	Crop Land
Swine	2	2	10	17	10	6	6	9	17	13	6	2	90	10
Beef	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	100	0
Dairy	4	4	9	14	9	7	7	9	14	12	7	4	50	50
Broiler	1	5	10	14	10	10	10	10	10	14	5	1	70	30
Layer	1	1	10	19	10	10	9	10	10	14	5	1	90	10

Wildlife

Wildlife deposit waste containing fecal coliform bacteria onto the land where it can be transported during a rainfall runoff event to nearby streams. Fecal coliform contributions from wildlife were represented in the model based on deer population. It was assumed that deer are uniformly distributed to forest land, pasture land, cropland and wetland areas. Fecal coliform loading rates due to deer were estimated (refer to Section 3.4.1 for discussion) to be 5.0×10^8 counts/animal/day. Using this rate and the assumption of equally distributed population of deer between forest and agricultural land uses, the fecal coliform load applied to the land surface was calculated to be 1.88×10^7 counts/acre/day. This contribution is considered a background loading to the stream.

2.5 Linking the Sources to the Indicators and Targets

Establishing the relationship between instream water quality and sources of fecal coliform, the pathogen indicator, is an important component of the TMDL. It provides the relative contribution of the sources, as well as a predictive examination of water quality resulting from changes in these source contributions.

2.5.1 Model Selection

The model selected for this TMDL needed to meet several objectives. The first objective was to simulate the time varying behavior of the deposition and transport of fecal coliform bacteria from the land surface to receiving water bodies.   The second was to use a continuous simulation period to identify the critical condition from which to develop the TMDL. Seasonal effects on the production and fate of fecal coliform bacteria were evaluated by use a continuous simulation period while varying the monthly loading rates.

The Nonpoint Source Model (NPSM) is a dynamic watershed model capable of simulating nonpoint source runoff and associated pollutant loads; accounting for point source discharges; and performing flow and water quality routing through stream reaches. It is based on the Hydrologic Simulation Program – FORTRAN (HSPF) and was chosen as the model to complete this TMDL because it incorporates the buildup and wash-off of pollutants on both pervious and impervious land surfaces. In addition, HSPF allows

discrete simulation of the required components of the TMDL (i.e., WLA and LA components).

The Watershed Characterization System (WCS), a geographic information system (GIS) interface, was used to display, analyze and compile spatial and attribute data. Available data sources included land use category, point source discharges, soil type and characteristics, population data (human and livestock), digital elevation data, stream characteristics, precipitation and flow data. Results from these analyses provided input to loading spreadsheets developed by Tetra Tech, Inc.; output from the spreadsheets included fecal coliform loading rates from surface runoff and from direct sources including leaking septic systems and livestock with stream access.

2.5.2 Model Setup

Crooked Creek was delineated into a single subwatershed based on a Reach File 1 (RF1) stream coverage and a Digital Elevation Model (DEM) of the area. The farthest downstream point of the delineation was the water quality sampling station CRK-5. Local meteorological data and local watershed and stream characteristics were used. Land use in the watershed was characterized based on Multi-Resolution Land Characteristics (MRLC) digital images dated 1990-1993. A continuous simulation period of 10-years (1/1/98 to 12/31/98) was used to analysis the TMDL as this incorporates a wide range of meteorological events for evaluating the worst-case scenario. This long time period also allows for the TMDL to be based on a range of seasonal conditions.

2.5.3 Calibration

The NPSM is driven by precipitation; therefore, it is important to calibrate hydrologic parameters prior to attempting a calibration for water quality. Long-term hourly precipitation data were obtained from the National Oceanic and Atmospheric Association (NOAA) and were used as input in the model for stream flow simulation. The predicted stream flow was then compared to the historic stream flow data from a continuous stream gage. The hydrologic parameters of infiltration, upper and lower zone storage, groundwater storage and recession, interflow, and evapotranspiration, were used to represent the hydrologic cycle and were adjusted until the simulated and observed hydrographs match. This hydrologic calibration is the foundation of the water quality model.

Water quality model calibration follows. The model parameters were adjusted until acceptable agreement was achieved between the simulated fecal concentrations and observed data from the water quality station. To calibrate the model, several parameters were adjusted including the rates of fecal coliform bacteria accumulation, wash-off rates, maximum storage of fecal coliform bacteria and contributions of direct sources. Water quality data are often limited but by matching the trends in simulated and observed concentrations resulting from peak and base flows, the model can be a reasonable predictor of instream water quality and be considered as calibrated. The inability to accurately simulate specific observed data points can sometimes be attributed to differences in rainfall at the meteorological gage and in the watershed as well as illicit point discharges.

Hydrologic Calibration

A continuous flow gage was not located in the Crooked Creek watershed; therefore, a hydrologic calibration was performed at a nearby gage (USGS 0240250 Sipsey Fork). The hydrologic parameters used to calibrate the model developed at the Sipsey Fork gage were assumed to apply to the Crooked Creek watershed and were used to develop the water quality model for Crooked Creek. The period from 1/1/89 to 12/31/89 was used as the calibration period for the hydrologic parameters as this was the extent of flow data and meteorological data were not available past 1998. The Huntsville, Alabama weather station provided the meteorological data. Relative fit of the modeled flow compared to the recorded flow is shown in Figure 3.
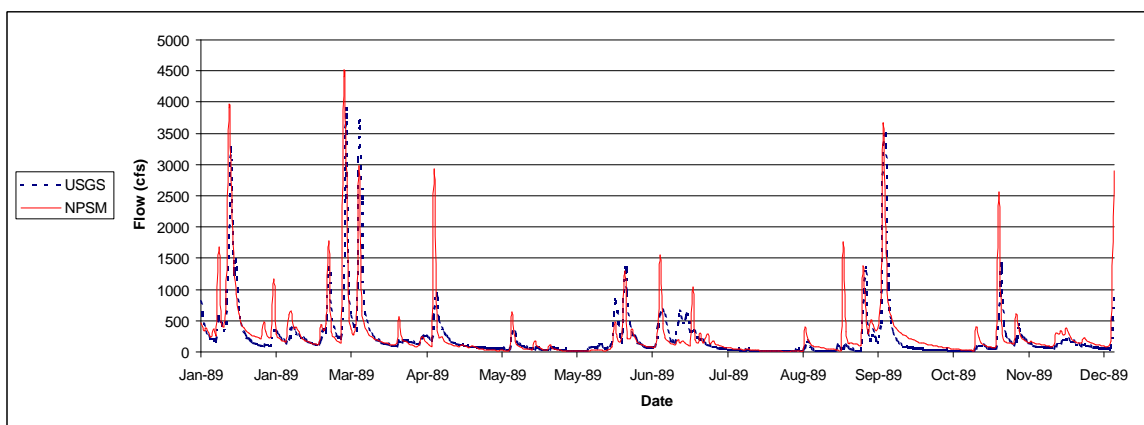

Figure 3. Daily modeled flow versus recorded data from USGS 0240250 Sipsey Fork.

Water Quality Calibration

Water quality samples collected at CRK-5 in 1991 and 1997 were compared to simulated concentrations in the water quality calibration. Appropriate model parameters were adjusted to obtain acceptable agreement between daily average simulated concentrations and observed data. Results shown in Figure 4 and 5 indicate that the model adequately simulates the response of fecal coliform bacteria during storm and low flow events.
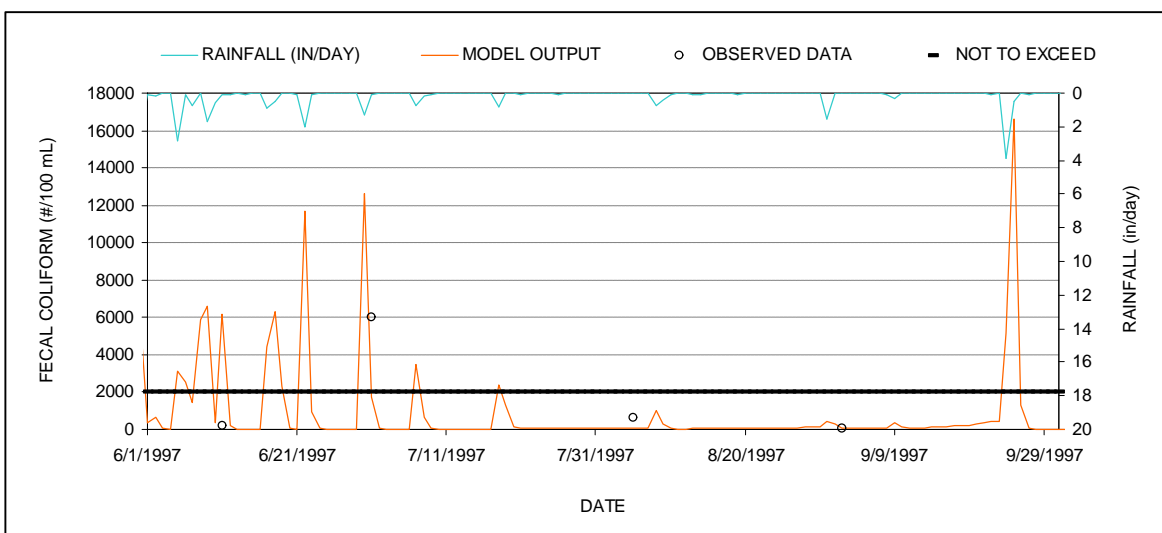

Figure 4. Simulated versus observed fecal coliform concentrations in 1997.
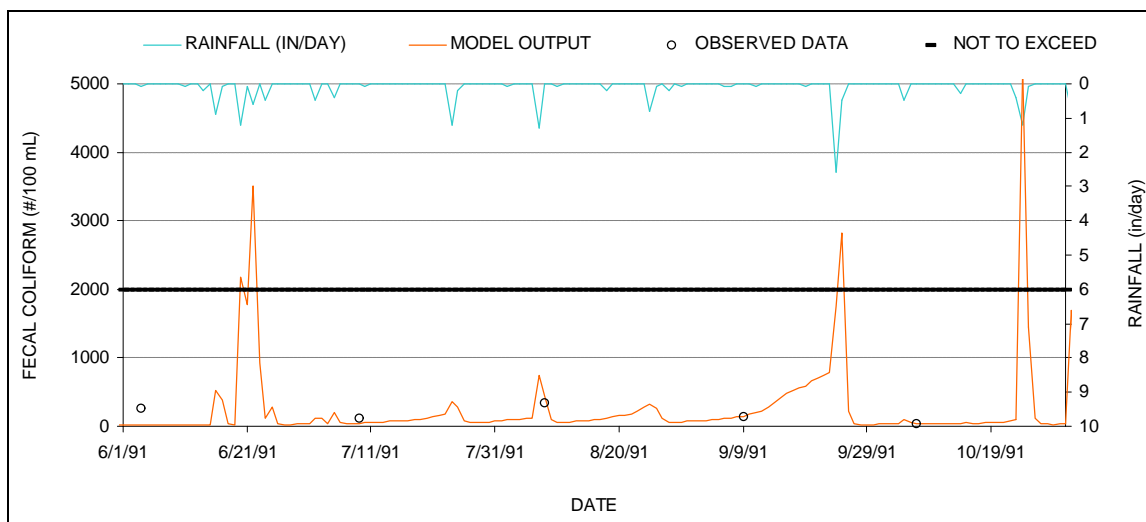
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Figure 5. Simulated versus observed (1991) fecal coliform concentrations at Station CRK-5 in Crooked Creek.

2.5.4 Results from Water Quality Modeling

Source loading rates representing existing conditions are shown in Table 6. In reviewing this table, it should be understood that *runoff from all lands* includes: deposits from grazing animals, an estimate of loading based on the deer population, an estimate of loads from urban areas, and loads from land applied manure. *Leaking septic systems* contains only information related to septic systems. *Miscellaneous sources* include two components: livestock with stream access as well as an estimate of unknown instream sources and illicit discharges. The model results in Table 6 indicate that stormwater runoff from all land uses has the most significant impact on fecal coliform bacteria loads. Loads from leaking septic systems and miscellaneous sources impact instream water quality only during periods of low flow. The existing fecal coliform load for Crooked Creek was determined in the following manner:

- The calibrated model was run for a 10-year period that included the critical condition.
- The daily fecal coliform load from all sources was summed for the 30-day critical period. This value represents the existing load.

Table 6. Summary of predicted existing coliform loads in the Crooked Creek watershed.

Watershed	Runoff From All Lands	Leaking Septic Systems	Miscellaneous Sources
	Counts/30 Days[1]	Counts/30 Days	Counts/30 Days[2]
Crooked Creek	4.28×10^{15}	1.20×10^{11}	4.89×10^{11}

[1] Includes grazing animals; deer population; land applied manure; and urban runoff.
[2] Includes livestock with stream access and illicit discharges.

2.6 Allocation

2.6.1 Total Maximum Daily Load (TMDL)

Once the model was calibrated for water quality, load reductions were applied until the simulated 30-day geometric mean of the fecal coliform bacteria counts did not exceed the water quality geometric mean standard of 200 counts/100 mL. The wasteload allocation (WLA) portion of the TMDL includes any NPDES permitted facilities. The load allocation (LA) portion includes coliform from grazing animals, animals with access to streams, urban runoff and illicit discharges, leaking septic systems and runoff from land applied animal manure.

An allocation scenario that predicts compliance with instream water quality standards requires the following reductions from the individual categories: an 87% reduction in stormwater runoff from all lands; a 60% reduction in leaking septic systems; and a 24% reduction in miscellaneous sources. The allocated loads and associated percent reductions for these categories are shown in Table 7. Final allocated values for the TMDL components are shown in Table 8.

Table 7. Predicted loads and percent reductions needed to meet water quality standards in Crooked Creek.

	Runoff From All Lands	Leaking Septic Systems	Miscellaneous Sources
	Counts/30 Days	Counts/30 Days	Counts/30 Days
Crooked Creek	5.73×10^{14}	4.81×10^{10}	3.73×10^{11}
% Reduction	87%	60%	24%

Table 8. TMDL components for Crooked Creek.

Watershed	WLA	LA	MOS	TMDL
	cnts/30 days	cnts/30 days		cnts/30 days
Crooked Creek	1.02×10^{10}	5.73×10^{14}	Explicit+Implicit	5.73×10^{14}

2.6.2 Seasonal Variation

A 10-year simulation period was used to assess loads and their affect on water quality; this period included seasonal variation. In addition, loading rates were varied monthly in the model. These rates were based on data obtained from the Watershed Characterization System and on monthly application rates of animal manure to cropland and pastureland.

2.6.3 Margin of Safety

Both an explicit and implicit margin of safety (MOS) were incorporated in this TMDL. The explicit MOS was incorporated into the LA component by reducing the loads entering the streams until the resultant instream concentration of fecal coliform bacteria during the critical period was 180 counts/100 mL (20 counts/100 mL below the water quality criterion or 10%). The implicit MOS was incorporated into the TMDL using conservative modeling techniques. These are:
- The TMDL target was developed against the most stringent water quality standard.
- Loads from leaking and failing septic systems were assumed to discharge directly to the stream with a constant concentration and flow when in reality they discharge to

the groundwater system where a portion of the fecal coliform may become incorporated into the soils prior to discharge into the stream.

- All land uses were modeled as if they were directly connected to the stream.

2.6.4 Critical Conditions

The critical condition for nonpoint source fecal coliform loading is an extended dry period followed by a rainfall runoff event. During the dry weather period, fecal coliform bacteria builds up on the land surface, and are transported to the stream by rainfall. The critical condition for point source loading occurs during periods of low stream flow when dilution is minimized. Both conditions are simulated in the water quality model.

The 10-year period from 1/1/89 to 12/31/98 was used to simulate a continuous 30-day geometric mean distribution to compare to the target (see Figure 6). This period contains a range of hydrological conditions that includes both low and high stream flows from which critical conditions were identified and used to derive the TMDL value.

The 30-day critical period in the model is the period preceding the largest simulated violation of the geometric mean standard (EPA 1991). The critical period excludes periods of model instability, when the simulated stream flow approaches zero and causes concentrations to become negative, or abnormal weather conditions such as floods or drought. Meeting water quality standards during the critical period ensures that water quality standards can be achieved during a range of meteorological events. For Crooked Creek, the critical period is 5/24/97 to 6/22/97.
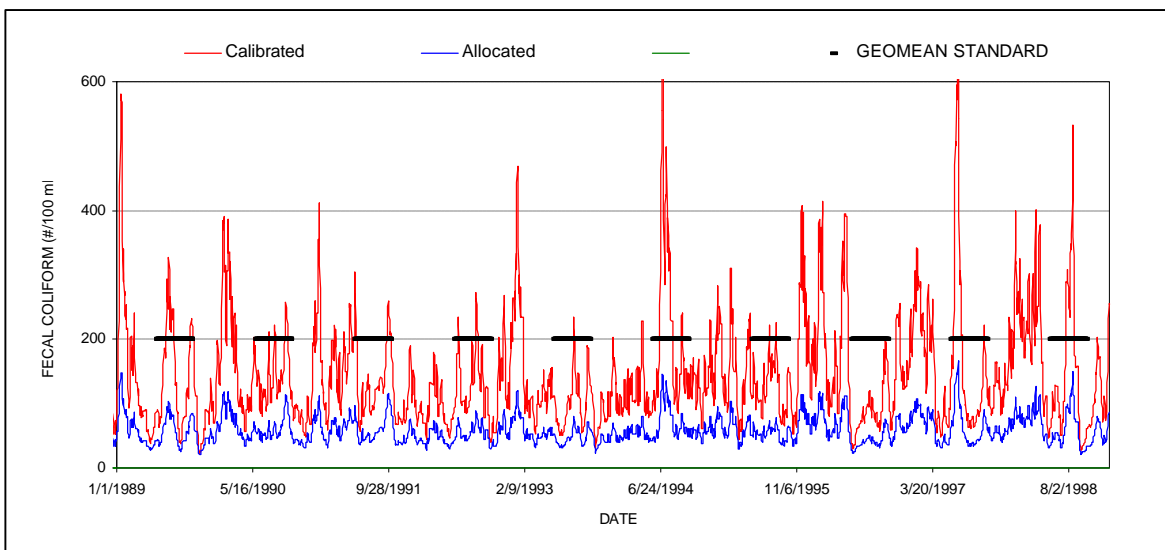

Figure 6. Geometric mean plot for Crooked Creek.

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APPENDIX A

GLOSSARY OF TERMS

4Q3. A probability-based statistic representing the 4- day average low flow occurring once in 3 years.

7Q10. 7Q10 is the 7-day average low flow occurring once in 10 years; this probability-based statistic is used in determining stream design flow conditions and for evaluating the water quality impact of effluent discharge limits.

Activated Sludge. A biologically-active solid (microorganisms) which is capable of stabilizing waste aerobically.

Advection. Bulk transport of the mass of discrete chemical or biological constituents by fluid flow within a receiving water. Advection describes the mass transport due to the velocity, or flow, of the waterbody.

Aerobic. Environmental conditions characterized by the presence of dissolved oxygen; used to describe biological or chemical processes that occur in the presence of oxygen.

Allocations. Allocations are that portion of a receiving water's loading capacity that is attributed to one of its existing or future sources (nonpoint or point) of pollution or to natural background sources. [Wasteload allocation (WLA) is that portion of the loading capacity allocated to an existing or future point source and a load allocation (LA) is that portion allocated to an existing or future nonpoint source or to natural background source. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.]

Ambient water quality. Concentration of water quality constituent as measured within the waterbody.

Anaerobic. Environmental condition characterized by zero oxygen levels. Describes biological and chemical processes that occur in the absence of oxygen.

Anthropogenic. Pertains to the [environmental] influence of human activities.

Aquatic ecosystem. A complex of biotic and abiotic components present in natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.

Assimilative capacity. The amount of a pollutant load that can be discharged to a specific waterbody without exceeding the water quality standards. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharges substance without impairing water quality or harming aquatic life.

Bacteria. Single-celled microorganisms that lack a fully-defined nucleus and contain no chlorophyll. Bacteria of the colifoni1 group are considered the primary indicators of fecal contamination and are often used to assess water quality.

BASINS (Better Assessment Science Integrating Point and Nonpoint Sources). A computer-run tool that contains an assessment and planning component that allows users t~ organize and display geographic information for selected watersheds. It also contains a modeling component to examine impacts of pollutant loadings from point and nonpoint sources and to characterize the overall condition of specific watersheds.

Benthic. Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.

Best management practices (BMPs). Methods, measures, or practices that are determined to be reasonable and cost-effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Biochemical oxygen demand (BOD). The amount of oxygen per unit volume of water required to bacterially or chemically oxidize (stabilize) the oxidizable matter in water. Biochemical oxygen demand measurements areusually conducted over specific time intervals (5,10,20,30 days). The term BOD generally refers to a standard 5-day BOD test.

Calcareous. Pertaining to or containing calcium carbonate.

Calibration. The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.

Channel. A natural stream that conveys water; a ditch or channel excavated for the flow of water.

Clean Water Act (CWA). The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 V.S.C. 1251 et seq. The CWA contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is Section 303(d), which establishes the TMDL program.

Coastal Zone. Lands and waters adjacent to the coast that exert an influence on the uses of the sea and its ecology, or whose uses and ecology are affected by the sea.

Coliform bacteria. See Total coliform bacteria.

Combined sewer overflows (CSOs). Discharge of a mixture of stormwater and domestic waste when the flow capacity of a sewer system is exceeded during rainstorms. CSOs discharged to receiving water can result in contamination problems that may prevent the attainment of water quality standards.

Combined sewer system (CSS). Sewer system that receives both domestic wastewater and stormwater and conducts the mixture to a treatment facility.

Concentration. Amount of a substance or material in a given unit volume of solution. Usually measured in milligrams per liter (mg/l) or parts per million (ppm).

Contamination. Act of polluting or making impure; any indication of chemical, sediment, or biological impurities.

Cost-share program. Program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs are paid by the producer.

Critical condition. The combination of environmental factors that results in just meeting the water quality criterion and has an acceptably low frequency of occurrence.

Cross-sectional area. Wet area ora waterbody normal to the longitudinal component of the flow.

Cryptosporidium. See protozoa.

Decay. Gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.

Decomposition. Metabolic breakdown of organic materials; the by-products formation releases energy and simple organics and inorganic compounds. (See also Respiration.)

Designated uses. Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.

Deterministic model. A model that does not include built-in variability: same input will always equal the same output.

Die-off rate. The first-order decay rate for bacteria, pathogens, and viruses. Die-off depends on the particular type of water body (i.e. stream, estuary, lake) and associated factors that influence mortality.

Digital Elevation Model (DEM). Elevation data which has been interpreted as a grid of variable cell size. A 90 meter-by-90 meter cell size is used in this work to delineate watersheds.

Dilution. Addition of less concentrated liquid (water) that results in a decrease in the original concentration.

Direct runoff. Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.

Discharge. Flow of surface water in a stream or canal or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.

Discharge permits (NPDES). A permit issued by the U.S. EP A or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or

industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. It is called the NPDES because the permit process was established under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.

Dispersion. The spreading of chemical or biological constituents, including pollutants, in various directions from a point source, at varying velocities depending on the differential instream flow characteristics.

Dissolved oxygen (DO). The amount of oxygen that is dissolved in water. It also refers to a measure of the amount of oxygen available for biochemical activity in a waterbody, and as an indicator of the quality of that water.

Dynamic model. A mathematical formulation describing the physical behavior of a system or a process and its temporal variability.

Ecosystem. An interactive system that includes the org~nisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.

Effluent. Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.

Effluent limitation. Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.

Endpoint. An endpoint is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints that are commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance. A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints.

Enhancement. In the context of restoration ecology, any improvement of a structural or functional attribute.

Enteric. Of or within the gastrointestinal tract.

Enterococci. A subgroup of the fecal streptococci that includes *S. faecalis* and *S. faecium.* The enterococci are differentiated from other streptococci by their ability to grow in 6.5% sodium chloride, at pH 9.6, and at 10°C and 45 °C. Enterococci are a valuable bacterial indicator for determining the extent of fecal contamination of recreational surface waters.

Epidemiology. All the elements contributing to the occurrence or non-occurrence ora disease in a population; ecology of a disease.

Escherichia coli. A subgroup of the fecal coliform bacteria. *E. coli* is part of the normal intestinal flora in humans and animals and is, therefore, a direct indicator of fecal contamination in a waterbody. The O157 strain, sometimes transmitted in contaminated waterbodies, can cause serious infection resulting in gastroenteritis. See Fecal coliform bacteria.

Estuarine number. Nondimensional parameter accounting for decay, tidal dispersion, and advection velocity. Used for classification of tidal rivers and estuarine systems.

Estuary. Brackish-water areas influenced by the tides where the mouth of the river meets the sea.

Existing use. Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).

Fecal coliform bacteria. A subset of total coliform bacteria that are present in the intestines or feces of warm-blooded animals. They are often used as indicators of the sanitary quality of water. They are measured by running the standard total coliform test at an elevated temperature (44.5°C). Fecal coliform is approximately 20% of total coliform. See also Total coliform bacteria.

Fecal streptococci. These bacteria include several varieties of streptococci that originate in the gastrointestinal tract of warm-blooded animals such as humans *(Streptococcus faecalis)* and domesticated animals such as cattle *(Streptococcus bovis)* and horses *(Streptococcus equinus).*

Feedlot. A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.

Flocculation. The process by which suspended colloidal or very fine particles are assembled into larger masses or floccules that eventually settle out of suspension.

Flux. Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.

Gastroenteritis. An inflammation of the stomach and the intestines.

Geochemical. Refers to chemical reactions related to earth materials such as soil, rocks, and water.

Giardia lamblia. See protozoa.

Hot Spots. Locations in a waterbodies or sediments where hazardous substances have accumulated to levels which may pose risks to aquatic life, wildlife, fisheries, or human health.

Hydrological Simulation Program (HSPF).A comprehensive modeling package that simulates water quantity and quality for a wide range of organic and inorganic pollutants from complex watersheds.

Hydrology. The study of the distribution, properties, and effects of water on the earth's surface, in.the soil and underlying rocks, and in the atmosphere.

Indicator. Measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.

Indicator organism. Organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.

Infectivity. Ability to infect a host.

Initial mixing zone. Region immediately downstream of an outfall where effluent dilution processes occur. Because of the combined effects of the effluent buoyancy, ambient stratification, and current, the prediction of initial dilution can be involved.

Insolation. Exposure to the sun's rays.

Irrigation. Applying water or wastewater to land areas to supply the water and nutrient needs of plants.

Karst geology. Solution cavities and closely-spaced sinkholes formed as a result of dissolution of carbonate bedrock.

Gradient. The rate of decrease (or increase) of one quantity with respect to another; for example, the rate of decrease of temperature with depth in a lake.

Groundwater. The supply of fresh water found beneath the earth's surface, usually in aquifers, which supply wells and springs. Because groundwater is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.

Land application. Discharge of wastewater onto the ground for treatment or reuse. (See: irrigation).

Leachate. Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, groundwater, or soil.

Load, Loading, Loading rate. The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.

Load allocation (LA). The portion *of* a receiving water's loading capacity that is attributed either to one *of* its existing *or* future nonpoint sources *of* pollution *or* to natural background sources. Load allocations are best estimates *of* the loading, which can range *from* reasonably accurate estimates to gross allotments, depending on the availability *of* data and appropriate techniques *for* predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished. (40 CFR 130.2(g))

Loading capacity (LC). The greatest amount of loading that a water can receive without violating water quality standards.

Low-flow. Stream flow during time periods where no precipitation is contributing to runoff to the stream and contributions from groundwater recharge are low. Low flow results in less water available for dilution of pollutants in the stream. Due to the limited flow, direct discharges to the stream dominate during low flow periods. Exceedences of water quality standards during low flow conditions are likely to be caused by direct discharges such as point sources, illicit discharges, and livestock or wildlife in the stream.

Margin of Safety (MOS). A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA Section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).

Mass balance. An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.

Mass loading. The quantity of a pollutant transported to a waterbody.

Mathematical model. A system of mathematical expressions that describe the spatial and temporal distribution of water quality constituents resulting from fluid transport and the one, or more, individual processes and interactions within some prototype aquatic ecosystem. A mathematical water quality model is used as the basis for waste load allocation evaluations.

Meningitis. Inflammation of the meninges, especially as a result of infection by bacteria or viruses.

Mitigation. Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those which restore, enhance, create, or replace damaged ecosystems.

Monitoring. Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.

Monte Carlo simulation. A stochastic modeling technique that involves the random selection of sets of input data for use in repetitive model runs. Probability distributions of receiving water quality concentrations are generated as the output of a Monte Carlo simulation.

Multi-Resolution Land Characteristics (MRLC). Land cover classification system based on Landsat satellite data. Grids are 30 meter size.

National Pollutant Discharge Elimination System (NPDES). The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under Sections 307, 402, 318, and 405 of the Clean Water Act.

Natural background levels. Natural background levels represent the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.

Natural waters. Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.

Nonpoint source. Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

Numeric Targets. A measurable value determined for the pollutant of concern which is expected to result in the attainment of water quality standards in the listed waterbody.

Organic matter. The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substance synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.

Outfall. Point where water flows from a conduit, stream, or drain.

Oxidation. The chemical union of oxygen with metals or organic compounds accompanied by a removal of hydrogen or another atom. It is an important factor for soil formation and permits the release of energy from cellular fuels.

Oxidation pond. A relatively shallow body of wastewater contained in an earthen basin; lagoon; stabilization pond.

Oxygen demand. Measure of the dissolved oxygen used by a system (microorganisms) in the oxidation of organic matter. See also biochemical oxygen demand.

Partition coefficients. Chemicals in solution are partitioned into dissolved and particulate adsorbed phase based on their corresponding sediment-to-water partitioning coefficient.

Pathogen. Disease-causing agent, especially microorganisms such as bacteria, protozoa, and viruses.

Permit. An authorization, license, or equivalent control document issued by EP A or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.

Permit Compliance System (PCS). Computerized management information system which contains data on NPDES permit-holding facilities. PCS keeps extensive records on more than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.

Phased approach. Under the phased approach to TMDL development, LAs and WLAs are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased

approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.

Point source. Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollutant. Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water. (CW A Section 502(6)).

Pollution. Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man- induced alteration of the physical, biological, chemical, and radiological integrity of water.

Pretreatment. The treatment of wastewater to remove or reduce contaminants prior to discharge into another treatment system or a receiving water.

Primary treatment. A basic wastewater treatment method that uses settling, skimming, and (usually) chlorination to remove solids, floating materials, and pathogens from wastewater. Primary treatment typically removes about 35 percent of biochemical oxygen demand (BOD) and less than half of the metals and toxic organic substances.

Protozoa. Single-celled organisms that reproduce by fission and occur primarily in the aquatic environment. Waterborne pathogenic protozoans of primary concern include *Giardia lamblia* and *Cryptosporidium,* both of which affect the gastrointestinal tract.

Public comment period. The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a *Federal Register* notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).

Publicly-Owned Treatment Works (POTW). Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.

Raw sewage. Untreated municipal sewage.

Reach File (RF). EPA developed datasets which are spatially accurate representations of streams. RF1 files use a scale of 1:250000 while RF3 files use a scale of 1:100000. RF2 files are no longer in use.

Receiving waters. Creeks, streams, rivers, lakes, estuaries, groundwater formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.

Residence time. Length of time that a pollutant remains within a section of a waterbody. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.

Respiration. Biochemical process by means of which cellular fuels are oxidized with the aid of oxygen to permit the release of the energy required to sustain life; during respiration, oxygen is consumed and carbon dioxide is released.

Restoration. Return of an ecosystem to a close approximation of its condition prior to disturbance.

Riparian zone. The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.

Runoff. That part of precipitation, snow melt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Safe Drinking Water Act. The Safe Drinking Water Act authorizes EPA to set national health-based standards for drinking water to protect against both naturally occurring and man-made contaminants that may be found in drinking water. EPA, states, and water systems then work together to make sure these standards are met.

Sanitary sewer overflow (SSO). When wastewater treatment systems overflow due to unforseen pipe blockages or breaks, unforseen structural, mechanical, or electrical failures, unusually wet weather conditions, insufficient system capacity, or a deteriorating system.

Scoping modeling. Involves simple, steady-state analytical solutions for a rough analysis of the problem.

Scour. To abrade and wear away. Used to describe the weathering away of a terrace or diversion channel or streambed. The clearing and digging action of flowing water, especially the downward erosion by stream water in sweeping away mud and silt on the outside of a meander or during flood events.

Secondary treatment. The second step in most publicly owned waste treatment systems, in which bacteria consume the organic parts of the waste. It is accomplished by bringing together waste, bacteria, and oxygen in trickling filters or in the activated sludge process. This treatment removes floating and settleable solids and about 90 percent of the oxygen-demanding substances and suspended solids. Disinfection is the final stage of secondary treatment. (See primary, tertiary treatment.)

Sediment. Organic or inorganic material often suspended in liquid that eventually settles to the bottom.

Sedimentation. Deposition or settlement of suspended matter in water, wastewater, or other liquids.

Septic system. An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a system of tile lines or a pit for disposal of the liquid effluent (sludge) that remains after decomposition of the solids by bacteria in the tank; must be pumped out periodically.

Sewer. A channel or conduit that carries wastewater and stormwater runoff from the source to a treatment plant or receiving stream. "Sanitary" sewers carry household, industrial, and commercial waste. "Storm" sewers carry runoff from rain or snow. "Combined" sewers handle both.

Simulation. Refers to the use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Slope. The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one uni~ vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04); degrees (2 degrees 18 minutes), or percent (4 percent).

Sorption. The adherence of ions or molecules in a gas or liquid to the surface of a solid particle with which they are in contact.

Stakeholder. Those parties likely to be affected by the TMDL.

Steady-state model. Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations.

STORET. U.S. Environmental Protection Agency (EPA) national water quality database for STORage and RETrieval (STORET). Mainframe water quality database that includes physical. chemical, and biological data measured in waterbodies throughout the United States.

Storm runoff. Stormwater runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or waterbodies or is routed into a drain or sewer system.

Stormwater. The portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, channels or pipes into a defined surface water channel, or a constructed infiltration facility.

Stormwater management models (SWMM). USEPA mathematical model that simulates the hydraulic operation of the combined sewer system and storm drainage sewershed.

Stratification (of waterbody). Formation of water layers each with specific physical, chemical, and biological characteristics. As the density of water decreases due to surface heating, a stable situation develops with lighter water overlaying heavier and denser water.

Stressor. Any physical, chemical, or biological entity that can induce an adverse response.

Surface runoff. Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of non point source pollutants.

Surface water. All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) a~d all springs, wells, or other groundwater collectors directly influenced by surface water.

Suspended solids or load. Organic and inorganic particles (sediment) suspended in and carried by a fluid (water). The suspension is governed by the upward components of turbulence, currents, or colloidal suspension. Suspended sediment usually consists of particles <0.1 mm, although size may vary according to current hydrological conditions. Particles between 0.1 mm and 1 mm may move as suspended or bedload.

Technology-based limits. Industry-specified effluent limitations applied to a discharge when it will not cause a violation of water quality standards at low stream flows. Usually applied to discharges into large rivers.

Tertiary treatment. Advanced cleaning of wastewater that goes beyond the secondary or biological stage, removing nutrients such as phosphorus, nitrogen, and most biochemical oxygen demand (BOD) and suspended solids.

Three-dimensional model (3-D). Mathematical model defined along three spatial coordinates where the water quality constituents are considered to vary over all three spatial coordinates of length, width, and depth.

Topography. The physical features of a surface area including relative elevations and the position of natural and man-made features.

Total coliform bacteria. A particular group of bacteria, found in the feces of warm-blooded animals, that are used as indicators of possible sewage pollution. They are characterized as aerobic or facultative anaerobic, gram-negative, nonspore-forming, rod-shaded bacteria which ferment lactose with gas formation within 48 hours at 35°. Note that many common soil bacteria are also total coliforms, but do not indicate fecal contamination. See also fecal coliform bacteria.

Total Maximum Daily Load (TMDL). The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, and a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.

Toxic substances. Those chemical substances which can potentially cause adverse affects on living organisms. Toxic substances include pesticides, plastics, heavy metals, detergent, solvent, or any other materials that are poisonous, carcinogenic, or otherwise directly harmful to human health and the environment as a result of dose or exposure concentration and exposure time. The toxicity of toxic substances is modified by variables such as temperature, chemical form, and availability.

Tributary. A lower order stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.

Turbidity. The amount of light that is scattered or absorbed by a fluid.

Two-dimensional model (2-D). Mathematical model defined along two spatial coordinates where the water quality constituents are considered averaged over the third remaining spatial coordinate. Examples of 2-D models include descriptions of the variability of water quality properties along: (a) the length and width of a river that incorporates vertical averaging or (b) length and depth of a river that incorporates lateral averaging across the width of the waterbody.

Unstratified. Indicates a vertically uniform or well-mixed condition in a waterbody. See also Stratification.

Urban runoff. Water containing pollutants like oil and grease from leaking cars and trucks; heavy metals from vehicle exhaust; soaps and grease removers; pesticides from gardens; domestic animal waste; and street debris. which washes into storm drains and enters surface waters.

Validation (of a model). Process of determining how well the mathematical representation of the physical processes of the model code describes the actual system behavior.

Verification (of a model). Testing the accuracy and predictive capabilities of the calibrated model on a data set independent of the data set used for calibration.

Virus. Submicroscopic pathogen consisting of a nucleic acid core surrounded by a protein coat. Requires a host in which to replicate (reproduce).

Wasteload allocation (WLA). The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h).

Wastewater. Usually refers to effluent from a sewage treatment plant.

Wastewater treatment. Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water in order to remove, reduce, or neutralize contaminants.

Water quality. The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.

Water quality criteria. Elements of state water quality standards expressed as constituent concentrations, levels, or narrative statement, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use.

Water quality standard. State or federal law or regulation consisting of a designated use or uses for the waters of the United States, water quality criteria for such waters based upon such uses, and an antidegradation policy and implementation procedures. Water quality standards protect the public health or welfare, enhance the quality of water and serve the purposes of the Clean Water Act.

Watershed. A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Wetlands. An area that is constantly or seasonally saturated by surface water or groundwater with vegetation adapted for life under those soil conditions, as in swamps, bogs, fens, marshes, and estuaries,